Review of the GMDD manuscript

The Flexible Modelling Framework for the Met Office Unified Model (Flex-UM, part of the UM 12.1 release)

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Summary:
The manuscript describes a flexible modelling framework (called Flex-UM) which broadens the climate model hierarchy capabilities of the U.K. Met Office's Unified Model (UM). Simplified physical parameterizations were added to Flex-UM which is part of an upcoming UM release. The parameterizations were originally designed by Frierson et al. (2006) and Frierson (2007) for an idealized moist version of the (now legacy) spectral transform model of the Geophysical Fluid Dynamics Laboratory (GFDL). In particular, simplified schemes for convection, large-scale precipitation, radiation, boundary layer mixing, and sea surface temperature (SST) boundary conditions were included. The purpose of the manuscript is to compare Flex-UM to (a) ERA5 reanalysis data, (b) aquaplanet simulations with another simplified modeling system called Isca, and to (c) comprehensive simulations of the UM (version GA7.0) in an aquaplanet configuration with both a slab-ocean and fixed SST boundary condition. The manuscript thereby aims at documenting the flow characteristics of Flex-UM, judging their realism, and presenting the results as a benchmark calculation that can be used by others for model intercomparisons.

The manuscript is purely descriptive and points out the similarities and differences between the ERA5 data, Flex-UM, Isca and UM GA7.0 in both the slab ocean and prescribed SST mode. No attempt is made to shed further light on the processes that lead to the differences. This approach is acceptable since the focus of the manuscript lies on the documentation of Flex-UM. In general, the manuscript is well written. However, it fails to serve as a benchmark for others due to the poor quality of the figures and some missing pieces of information, such as the exact configuration of the simplified Betts-Miller (SBM) scheme, and the omission of the surface fluxes in the description. There are also some minor inconsistencies, such as unit mismatches in the definition of the latent heat flux. These are outlined below. The major deficiency of the manuscript (but potentially easy to correct) is the poor choice of the color schemes (often white to dark blue or dark blue to dark red which too many shades) which makes it impossible to clearly see the data. This is especially true in a printed copy of the manuscript. In addition, it is clear from many of the figures like the relative humidity and streamfunction figures (including their difference plots) that the chosen min/max ranges for the color schemes are inadequate and that the colors saturate. This fails to show the actual circulation data, which is the main message of the manuscript. All figures need to be replotted. The main goal needs to be the readability of the data, including a display of their actual min/max range. Once corrected, the manuscript will be a valuable addition to the literature that describes model hierarchies.

Specific comments:

1) Replot all figures with adequate min/max ranges (capturing the actual data ranges, avoid the large areas with saturated colors) and select clearly distinguishable color schemes.
2) Page 1, line 8, typo: should read 'Geophysical Fluid Dynamics Laboratory'
3) Page 4, line 14: the surface fluxes need to be included in the list, and the treatment of the surface fluxes needs to be described in section 2.

4) Page 4, line 34: Frierson (2007) presents the SBM scheme in many configurations, e.g., with the 'shallower shallow convection scheme', 'no shallow' or 'SBM with qref'. In addition, Frierson explores various parameter ranges for the tuning parameters 'relative humidity threshold' and 'relaxation time scale'. The exact choices for the Flex-UM simulations need to be added to the manuscript.
5) Page 5, line 12: which Frierson model is meant here? None of the listed Frierson papers use a fixed SST. Define the latitude symbol in the definition of the SST. It would be helpful to see the actual SST profile to have a better understanding how it compares to the more standard SST profiles listed in the aquaplanet paper by Neale and Hoskins (2000).
6) Page 5, line 25 and page 6, line 8: Flex-UM uses a 2.5 slab ocean depth, Frierson et al. (2006) selected a 2.4 m slab ocean depth. Why was a different h value chosen in Flex-UM? The manuscript claims that it follows Frierson et al. (2006).
7) Page 6, lines 27 and 28: the authors mean 'extrapolation', not interpolation.
8) Page 7, provide details how the sensible heat (SH) and latent heat (LH) fluxes are defined and computed for Eq. (1) (see also comment 2) which highlights the omission of the surface fluxes in the description).
   It is stated that LH = $L_c P$ where P is the precipitation. Correct this to 'precipitation rate'. It is true that ideally the surface evaporation is balanced by the precipitation when averaged over long time periods. Did the authors check whether this is true for Flex-UM? There is a unit mismatch here since P is displayed in units of mm/day (m/s) in all figures. However, the rain rate P in the equation needs units of kg/(m^2s) which when multiplied with the latent heat of condensation L_c (J/kg) lead to units of W/m^2 for the energy budget. Use this opportunity to also clarify the apparent sign inconsistency between the definitions of the evaporative fluxes:
   $E = \rho_a C |v_a| (q_a - q^*_a)$ (Frierson et al. (2006), Eq. (11)), used in Flex-UM?
   $E = \rho_a C |v_a| (q^*_a - q_a)$ (Vallis et al. (2018), Eq. (10), defined for the Isca model)
9) Caption of Figure 1: The black contour in (c) on top of the dark blue is invisible in a printed copy.
10) Page 10, line 13: when computing the mass stream function was the time-mean zonal-mean of v and ω computed first before the integration of the velocity components?
11) Page 10, figure 2 and figure 3: it seems wrong that the Isca model shows a hemispheric asymmetry in the gray (no-data) area near the surface in the Southern Hemisphere. What is the reason for this or is this a plotting error? A 10-year average should not have such a clear asymmetry. This question also addresses the hemispheric asymmetry in the stream function plots in Figs. 3, 6 and 9.
12) Precipitation rate plots (Fig. 4, 7, 10): since there are almost no longitudinal variations in P in these plots, it would be a lot clearer to show the zonal-mean P as line plots instead. This will also make it easier to see the min/max ranges of P and the P differences.
13) Captions of Figs. 4, 7, 10: typo, should read mm day^{-1}